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Abstract. *A two-year project was begun in Iowa in 2002 to test the decay performance, air and water environmental impacts, and bio-security of using composting for emergency disposal of cattle carcasses in the event of a foot-and-mouth disease outbreak. Of the three emergency cover materials tested to date, silage produced the highest and most sustained internal heat, the most rapid and thorough carcass decomposition, and the most rapid destruction of avian vaccine viruses introduced into the piles for bio-security testing. Although internal temperatures within ground cornstalk cover material were much lower than in the silage, carcass decomposition appeared to occur almost as rapidly as in the silage. The cornstalk material produced more collectable leachate with higher pollutant concentrations than the silage. Downwind odor from test units constructed with ground cornstalk, which has a much higher air permeability coefficient than silage, appeared to be strongest and more frequent during the initial 2 – 3 weeks following construction of the piles.*

Keywords. animal carcass, mortality, disposal, composting

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Introduction

Following the foot-and-mouth disease (FMD) epidemic in Great Britain in 2001, many livestock-producing countries have a renewed interest in the environmental impacts and bio-security of various methods that can be used to dispose of large numbers of animal mortalities. Evaluation of previous FMD outbreaks throughout the world (Daggupaty and Sellers, 1990; Kitching, 1998; Sellers and Daggupaty, 1990), have demonstrated the potential for air-borne transmission of the disease, as well as through improper transport of infected animals or carcasses. The fact that FMD can spread very rapidly emphasizes the extreme importance of rapid depopulation of infected herds, and a resulting need for disposal methods that can be accomplished without specialized equipment or the need to transport infected carcasses long distances. Recent reports commissioned by Great Britain and the European Union emphasize a need for improved animal mortality disposal methods (The Royal Society, 2002; European Commission, 2002).

In 2002 the Iowa Department of Natural Resources (IDNR) asked researchers at Iowa State University to investigate the feasibility, environmental impacts, and biosecurity of using on-farm composting for emergency disposal of beef or dairy animals in the event of a foot-and-mouth disease outbreak in the State of Iowa.

Although rendering, burial, and incineration have been the most common emergency disposal methods used in the past, IDNR listed the following reasons for investigation of composting:

- The number of rendering facilities in Iowa has declined substantially in the past 20 years, and long distance transport of infected carcasses to rendering facilities during an animal disease emergency could increase the risks of disease transmission;
- Incineration of carcasses in open pyres requires large amounts of fuel that are not readily available in Iowa, and use of open pyre incineration in Great Britain during the 2001 epidemic reportedly caused serious air pollution;
- Nearly 40% of Iowa's land area is characterized by shallow bedrock or seasonally high water tables that could be contaminated by mass burial of large numbers of animals; and
- Frozen ground during the winter season makes burial extremely difficult for 4-5 months each year.

Project Scope & Objectives

Based on preliminary discussions with the project sponsor (IDNR), windrows constructed with a tractor-loader were identified as the composting system most likely to be used by Iowa cattle producers during a disease emergency. Unlike typical solid waste composting systems, however, windrows for emergency disposal of diseased animals would not be turned to avoid spreading the foot-and-mouth virus.

IDNR officials stipulated that all field tests be done using full sized 350 –550 kg (800-1200 lb) cattle carcasses, and that all experimental test units include a minimum of two to four cattle carcasses so as to simulate full scale operating conditions likely to occur during a disease emergency.

The research was designed to address specific performance factors in three major areas of concern.

Compost System Construction and Performance

- time needed for complete carcass decay under varying seasonal weather conditions;

- temporal and spatial distribution of internal temperatures;
- quantity and relative performance of cover materials; and
- windrow deterioration caused by wind and water erosion or animal intrusion.

Environmental Impact

- air quality (odor) during carcass decomposition;
- quantity and quality of leachate production; and
- soil contamination beneath the composting windrows.

Biosecurity

- ability of composting windrows to retain and prevent airborne transmission of viruses
- viral inactivation within the composting process.

In addition to the field tests mentioned above, key physical and biological properties of the cover materials used in the field tests, and of a variety of alternative cover materials that might be used in an emergency, were to be tested in the laboratory. These tests are designed to identify and rank the potential performance of a wider range of potential cover materials than could be subjected to full-scale field testing. The laboratory test values, and field weather and internal temperature data, will also be used to develop a dynamic computer model of the composting process.

Methods

Composting System Construction and Performance

A 3 X 3 experimental design with 3 replications is used to evaluate the performance of three cover materials during three critical moisture/temperature scenarios. Cover materials selected for field testing included silage, ground cornstalk, and yard waste compost. The first two were selected because they are normally available throughout the year on most dairy and beef cattle farms. Though not normally found on cattle farms, yard waste compost was identified as a potential emergency cover material that is stockpiled and available at 60 municipal/industrial composting operations throughout the Iowa.

Performance is evaluated for trials that are initiated under critical weather conditions that occur throughout the year. These include warm/dry conditions likely to occur in mid to late summer, cold/dry conditions typical of wintertime operation, and cool/wet conditions that occur in the spring. As indicated by their titles, these conditions feature moisture and temperature extremes that would be likely to impede vigorous microbial activity, and/or lead to undesirable odor and leachate releases.

Experimental units are 20-foot long windrow sections (triangular cross-section) constructed with a tractor loader. Each unit contains four 800-1200 lb cattle carcasses purchased from a regional rendering company. Animals are placed on an 18 to 24-inch thick base layer of cover material and then covered with the same material. To maintain a low windrow profile that is less prone to wind erosion damage, carcasses in each experimental unit are placed in a single layer (not stacked) consisting of two parallel rows each containing two animals.

Microbial activity and decay are evaluated through internal temperature monitoring and periodic excavation of the test piles. Twenty thermocouples are embedded in each experimental unit, 4 between adjacent carcasses in the central “core” of the windrow, 8 within the 15-30 cm “carcass

surface" envelope of cover material surrounding the carcasses, and 8 in the "outer envelope" of the pile located approximately 30-45 cm from the carcasses. The thermocouples are read with a Campbell Scientific data logger every two minutes and hourly average values are stored for downloading. A weather station near the piles monitors and records ambient air temperature, wind speed and direction, relative humidity, and precipitation.

During the first year of the project carcass decay rate was monitored indirectly by photographing the windrows, and by partially excavating and photographing the interior every after 100 -150 days.

Environmental Impact

Odor is observed 100 and 500 feet downwind of the windrows on a weekly basis during the 4-6 weeks after pile construction. After unsuccessful attempts to use a scentometer for these observations, this approach was abandoned in favor of unaided odor observations.

Quantity and quality of leachate production is evaluated by placing large plastic covered plywood leachate collection trays under each pair of carcasses. The trays are designed to capture leachate from beneath the carcasses and from under the edges of the windrow where only the cover material would contribute to leachate. Leachate samples are tested for total solids, total organic carbon (TOC), nitrate (NO_3), and ammonium (NH4).

Soil quality is monitored by collecting 3-cm diameter by 1.2 m deep soil cores from beneath the experimental units. Four cores are collected prior to construction of the windrows, and four more will be collected after the experimental units are disassembled and spread on cropland. The soil cores are segmented into 30 cm sub-samples and tested for soil-attached NH4-N, and for dissolved NH4-N, NO3-N, Cl, and TOC in the soil moisture.

Biosecurity

Bio-Containment

The ability of the windrow composting system to prevent wind blown release of disease-causing viral organisms is evaluated by contaminating the surfaces of the cattle carcasses with non-pathogenic strains of two avian viruses prior to covering them. A commercially licensed vaccine strain of avian encephalomyelitis (AE) virus is used to emulate foot-and-mouth (FMD) virus. Like the FMD virus, AE virus is categorized in the family picornaviridae. These are very small, single-stranded, RNA type, non-enveloped types of viruses that are very stable in a variety of environmental conditions. Influenza virus also is being used to challenge the composting process since many types of influenza viruses commonly threaten animal populations. Influenza viruses are typically single-stranded RNA viruses that possess an envelope and are usually less stable in the environment than non-enveloped viruses. A commercially licensed B1Lasota strain of Newcastle disease virus (NDV) is being used to emulate influenza virus in this study.

Windblown release and transmission of the vaccine viruses is monitored by placing six cages containing four specific pathogen free (SPF) chickens each approximately 10 feet from the windrows. Blood samples are drawn from the sentinel poultry on the day they are placed in the field, and at the end of weeks 1,2,3,4,6, 8, and 10. Bloods samples are tested for NDV antibodies using the hemagglutination-Inhibition (HI) test as described in (American Assoc. of Avian Pathologists, 1989). AE antibodies are tested using an Enzyme-Linked Immunosorbent Assay (ELISA) kit purchased from IDEXX Laboratories, Inc. of Westbrook, ME.

Contamination of the cattle carcasses is accomplished by inoculating 20 dozen 10-day-old embryonating chicken eggs with NDV vaccine (B1 type, B1 strain, American Scientific Laboratories, Inc.) and incubating them at 37 °C and 60% relative humidity for 4 days. A similar number of 6-day-old embryonating eggs also are inoculated with AE vaccine strain (Tremblex, 1143 Calnek strain, Vineland Laboratories) and incubated at 37 °C and 60 % relative humidity for 12 days. Approximately 6 dozen of the infected eggs are placed on and around the cattle carcasses in each experimental unit before covering the carcasses.

All sentinel chickens used in the study are grown from Specific Pathogen Free (SPF) eggs that are incubated, hatched, and raised under SPF conditions. Two 12-week-old SPF chickens were spray-vaccinated with the NDV vaccine, and two with the AE vaccine, to serve as positive controls to verify the infectivity of the NDV and AE vaccine organisms. Blood samples were collected from these birds at pre-vaccination; and 1-week, 3-weeks, and 10-weeks post vaccination.

Virus Inactivation

The same NDV and AE vaccine organisms used to test the bio-containment ability of the composting system are also used to assess the ability of composting to inactivate viruses. Eight plastic cryogenic vials, and 4 dialysis cassettes, each loaded with 1 ml of each vaccine, are placed into each experimental unit next to one of the cattle carcasses. The cryogenic vials expose the viruses to internal temperatures within the composting process, but protect them from changes in pH and moisture, and from acids and gases produced during decay. The dialysis cassettes consist of plastic frames with gas permeable membrane walls that can contain the viral samples while exposing the organisms to internal temperature, gas, and pH conditions within the compost pile.

Cryogenic vials are retrieved at day 1, and weeks 1,2,3,6,8, and 10. Cassettes were retrieved collected at the end of weeks 1, 2, 3, and 4. In both cases retrieval is accomplished through PVC pipe access ports inserted into the compost piles at the time of construction.

Results & Discussion

Results presented here are for two initial trials conducted during the 1st year of this project. Trial # 1 was begun in late August of 2002 and is representative of warm/dry seasonal conditions. Trial # 2, begun in November of 2002, represents performance under cold/dry seasonal condtions.

Initial Cover Material Characterization

Table 1 shows moisture content, volatile solids, bulk density, free air space (FAS), permeability coefficient, respiration rate, and carbon to nitrogen (C:N) ration for the three cover materials used in the study.

The ground corn stalk appears to have the lowest potential for self-heating and heat retention of the three cover materials. Initial moisture content (17%) for the corn stalk is very low, and its C:N ratio of 66 is considerably higher than the 20 -30 that is considered optimal. The cornstalk also has a very open pore structure as evidenced by its low bulk density and relatively high permeability coefficient. These characteristics suggest that air infiltration and subsequent loss of heat and release of odorous volatile chemicals may be a problem for this cover material.

The silage has much better potential for self-heating and heat retention than the cornstalk. It's initial moisture content is 60-70 %, and its C:N ratio is around 21. The bulk density of the silage is about 10 times that of the cornstalk, and its permeability coefficient is only about 1/6th of the

cornstalk permeability. Taken together, these suggest that wind driven air infiltration and heat loss are less likely for the silage than for the cornstalk.

The yard waste compost is a very mature compost material with a soil-like texture. It's bulk density is almost twice that of the silage, and nearly 20 times that of the ground cornstalk. The C:N ratio of the yard waste suggests potential for further degradation and self heating, but its low moisture content (18%) makes a high level of microbial unlikely. The permeability coefficient for the yard waste compost is only about 1% and 7%, respectively, of the cornstalk and silage suggesting that this material may not allow much air or volatile chemical movement through the matrix.

Respiration tests conducted at 35 °C and 50% moisture content, show the yard waste compost to have the lowest potential for microbial activity, the silage has moderate potential and, under optimal moisture and temperature conditions the cornstalk material had a relatively high potential for decay.

Composting System Performance

Internal Temperature Profiles

Figure 1 shows daily average temperatures recorded in the "core", "carcass surface", "outer envelope" zones of the cornstalk unit of trial # 1. Temperatures in the core area between carcasses were the warmest, and those in the outer envelope the coolest.

Average daily temperature data for all experimental units in trial 1 (figure 2) confirm that the cornstalk unit generally exhibited the lowest internal temperatures. After ambient air temperatures dropped below 5 °C internal temperatures within the cornstalk pile dropped considerably, nearly equaling the external air temperatures during the January -March time period. Throughout trial 1, the silage test unit consistently produced the highest average internal temperatures, often 10 - 20 °C higher than those in the yard waste compost during the first 100 days. Internal temperatures in the yard waste tended to respond much more slowly than the silage or cornstalks to ambient air temperature fluctuations. This is probably due to its high bulk density and relatively low air permeability coefficient.

Average internal temperatures during the first 150 days of trial 2 are shown in figure 3. As with trial 1, temperatures in the cornstalk pile are the lowest, and those in the silage were highest although yard waste temperatures occasionally exceeded those in the silage. It should be noted that the silage trial experienced substantial subsidence (from a peak height of 7 feet, to less than 3 feet) during the first 60-90 days. As a result, the thickness of the silage envelope, and its ability to retain heat, decreased dramatically.

Carcass Degradation

To date, only the first trial has been excavated to observe and photograph carcass decay. Excavation was done with a backhoe approximately 110 days after the first trial was initiated. A small portion of each of the three experimental units in trial 1 was excavated until carcass remains could be observed.

As anticipated due to the high internal temperatures and rapid pile subsidence observed during the initial 100 days, carcass decay within the silage trial appeared to be nearing completion. Excavation revealed mostly skeletal remains with almost no soft tissue attached. Odors emitted during excavation were minimal.

Despite low initial moisture content (and almost no precipitation) and internal temperatures that averaged 20 °C lower than the silage, carcass decay was very good. Like the silage trial, the remains encountered within the cornstalk unit consisted of large bones that were mostly dry and free of soft tissues (Figure 4). As for the silage, odors during excavation were minimal.

Despite average internal temperatures 5 – 10 °C greater than for the corn stalk unit, carcass decay in the yard waste compost was the poorest of the three experimental units in trial 1. A large mass of un-decomposed carcass and manure was encountered in the core of the pile. Odors were strong and internal conditions appeared to be very anaerobic.

Environmental

Odor/Air Quality

Intermittent carcass decay odors were noted during the first 2 –3 weeks of trials 1 and 2. In nearly all instances, these were detected in the immediate vicinity of the piles, generally not more than 100 feet down wind. The strongest odors appeared to originate from the cornstalk units. The masking effect of odors emitted by the cover material itself made it difficult to specifically identify decay odors associated with the experimental units constructed from silage. Little if any odor was attributed to the yard waste units. As noted earlier, the yard waste compost has a higher bulk density and finer texture than either the cornstalk or silage cover materials. This is believed to greatly limit gas movement into our out of the pile. Adsorption of odorous chemicals by organic carbon in the yard waste compost also may help to contain odor.

Leachate

Due to much dryer than normal dry weather throughout trials 1 and 2, leachate production has been minimal. Table 2 summarizes selected chemical characteristics of leachate collected from beneath trial 1 begun in late August of 2002. The cornstalk unit of trial 1 produced the largest number (12) of leachate samples. The silage unit produced 5 samples, and no leachate could be collected from beneath the yard waste unit in trial 1. Attempts to collect leachate from trial 2, begun in November, have been unsuccessful.

Total solids, TOC, NH_3, and NO_3 nitrate concentrations in leachate from beneath the carcasses in the center of the cornstalk unit were approximately 24X, 45X, 91X, and 5 X higher (respectively) than in leachate collected near the edges of the windrow where there are no carcasses. The silage experimental unit, however, showed relatively little difference in the quality of leachate collected at the center and edges, and the pollutant concentrations in leachate from the silage unit was typically ½ or less of that from the cornstalk unit.

Soil Quality

Since the two trials reported on here are still on-going at this time, post-trial soil cores have not been collected and no soil impact data can be reported.

Biosecurity

Bio-containment

Exposure of SPF control poultry to the NDV and AE vaccine viruses prior to the start of trial 1 showed that blood samples from all control birds were negative for antibodies for both viruses prior to exposure. As shown in Figure 4, however, blood samples for control birds showed positive responses to NDV exposure within 1 week, and AE exposure within 3 weeks.

None of the 24 SPF birds stationed in cages around the composting trial showed a positive immune system response to NDV or AE viruses during the 1st ten weeks of trial 1.

Virus Inactivation

Ten sub-samples drawn from the NDV vials and dialysis cassettes retrieved from trials 1 and 2 were evaluated for the presence of live virus. As shown in Table 3, NDV samples embedded within trial 1 begun during warm dry weather generally survived less than 24 hours. None of the samples in cryogenic vials survived more than a day in the corn stalk and silage test piles. About 30% of samples in the yard waste survived for 1 day, but none of the vials collected after day 1 from any of the test units contained live NDV virus. Similarly, none of the dialysis cassettes retrieved on a weekly basis from the corn stalk and silage units during the 1st four weeks of the study contained live viruses. Unfortunately, dialysis cassettes could not be retrieved from the yard waste compost unit in trial 1 due to plugging of the retrieval port with decomposition products.

During trial 2, which was initiated during much cooler weather in November, live NDV virus survived in cryogenic vials embedded within the corn stalk and yard waste trials for two weeks. Survival in the silage windrow was much shorter. None of the vials collected from the silage trial after 24 hours was found to contain live NDV organisms.

Dialysis cassettes retrieved after 24 hours from all three test units in trial 2 contained live NDV viruses. Nine of the remaining 12 cassettes collected during the next four weeks were ruptured, presumably due to microbial attack on the dialysis membranes. None of the remaining three cassettes contained live NDV virus.

Analysis of retrieved vials and cassettes containing AE virus were inconclusive as none of the sub-samples produced positive results despite the fact that control birds exposed to the virus did test positive. While these results may signal very rapid inactivation of the AE virus, it may also indicate that standard assay procedures used pathogenic strains of AE may not be reliable indicators for vaccine strains of AE. Work is now underway to develop polymerase chain reaction procedures to positively confirm the presence of RNA from vaccine strains of the AE virus.

Conclusions

Preliminary data were collected during the first two of 27 replicated seasonal trials designed to evaluate the potential for using windrow composting for emergency disposal of diseased cattle. Corn silage, ground cornstalk bales, and finished yard waste compost were tested to determine their performance as cover materials for the carcasses. These particular materials were selected because they are expected to be readily available, in quantity, on or near most cattle farms in Iowa.

Internal temperature monitoring at 20 locations within each test unit showed that the average temperature is typically lowest within windrows consisting of ground cornstalks, highest in windrows constructed with corn silage, and intermediate in piles where yard waste compost was used as cover material.

Partial excavation 110 days after construction showed that decomposition of 450 kg cattle was very advanced in both the silage and cornstalk test units. Carcass remains in these piles were largely skeletal with little evidence of soft tissues of any kind. Decomposition of cattle composted in yard waste compost, however, took place much more slowly.

Odor evaluations were based on observations at the piles, and 100 and 500 feet downwind. Decay odor typically was noticeable no more than 100 feet down wind, and this generally dissipated within 2 – 3 weeks of pile construction. In general, odors appeared to originate primarily from piles constructed with ground cornstalk. Low bulk density and relatively high air permeability coefficient are believed to be key factors leading to odor releases from the ground cornstalks.

Due to dry weather, only small quantities of leachate were collected from the silage and cornstalk test units during the initial trial begun in August. No leachate could be collected from the initial yard waste compost trial, nor could leachate be collected from any of the test units begun during winter weather. Leachate samples were tested for TOC, total solids, ammonia, and nitrate. Pollutant concentrations within leachate from the cornstalk test unit were roughly twice those found in leachate from the silage unit. Leachate from the silage contained uniformly high pollutant concentrations at all locations throughout the pile. Leachate from the cornstalk test piles, however, was much more contaminated at locations beneath the cattle carcasses than at locations that were not beneath the carcasses.

Weekly blood samples drawn from pathogen-free poultry stationed around the perimeter of the compost piles during the first ten weeks of trial 1 all tested negative for immune system responses to two avian vaccine viruses placed on the cattle carcasses and the surrounding cover material at the time the compost piles were constructed.

Samples of two avian poultry vaccine viruses retrieved from the test piles at weekly intervals indicated that Newcastle disease virus was killed or inactivated within 2-3 weeks. Similar tests for avian encephalomyelitis vaccine virus survival were inconclusive.

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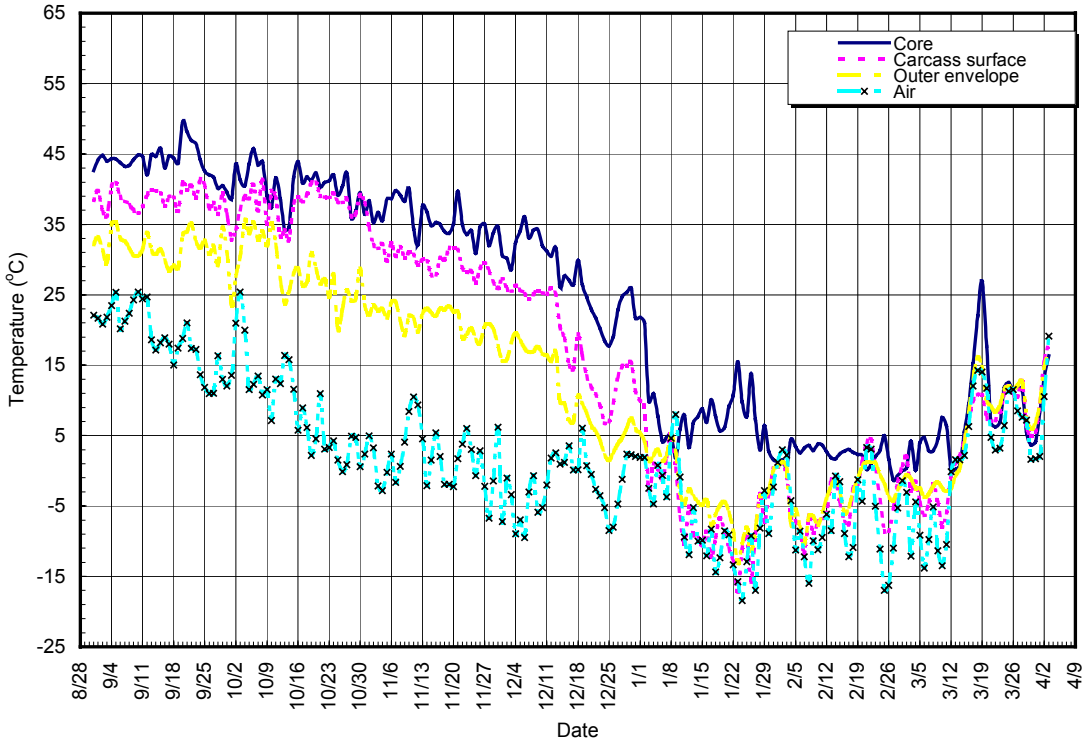

Figure 1. Daily average ambient air & internal temperatures for cornstalk trial #1 (warm/dry conditions).

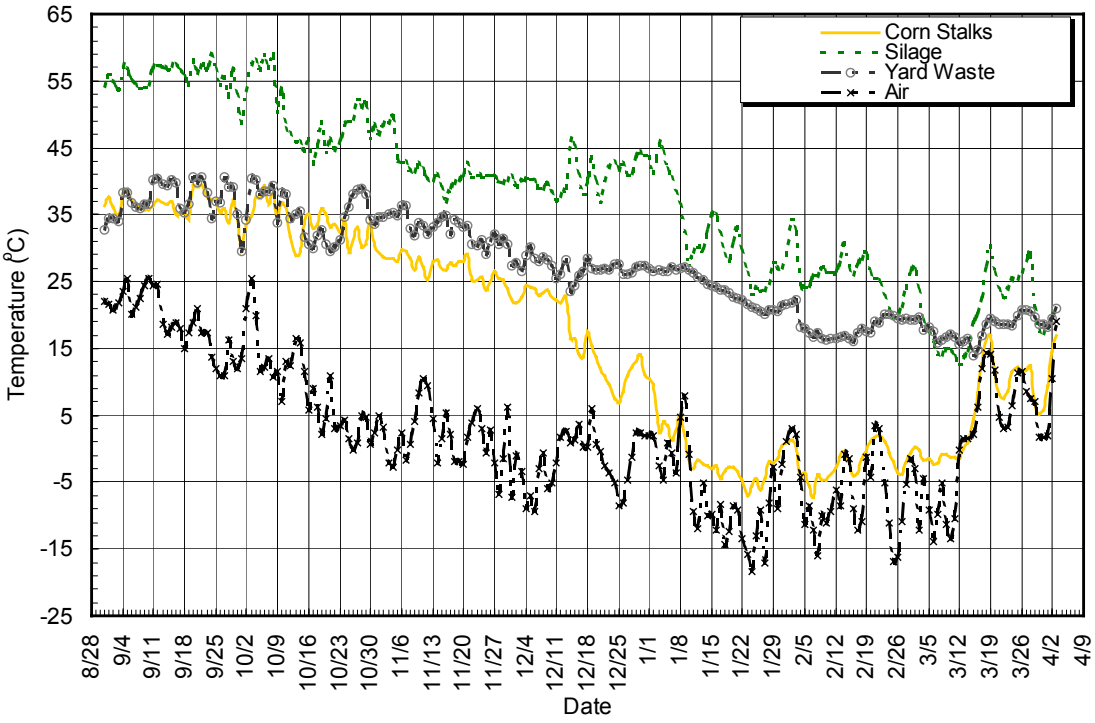

Figure 2. Average ambient air and internal temperatures for all experimental units in trial #1 (warm/dry conditions).

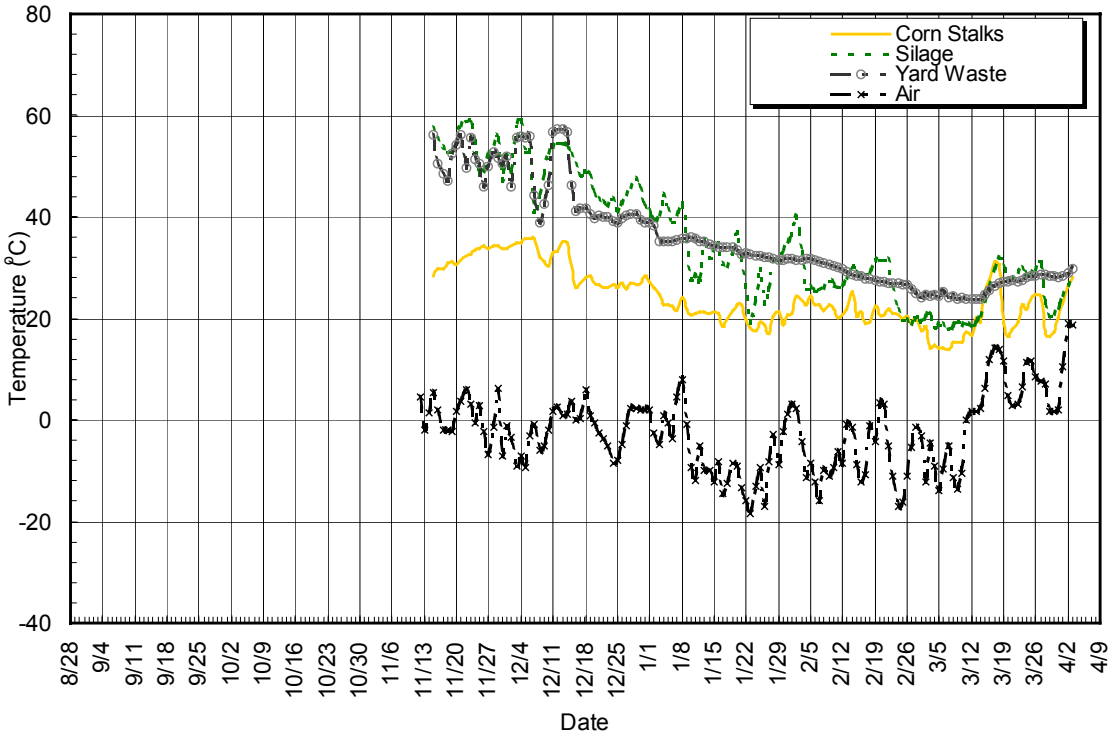

Figure 3. Average ambient air & internal temperatures for all experimental units in trial #2 (cold/dry conditions).

Figure 4. Example of skeletal remains found in trial 1 corn stalk test after 110 days of composting.

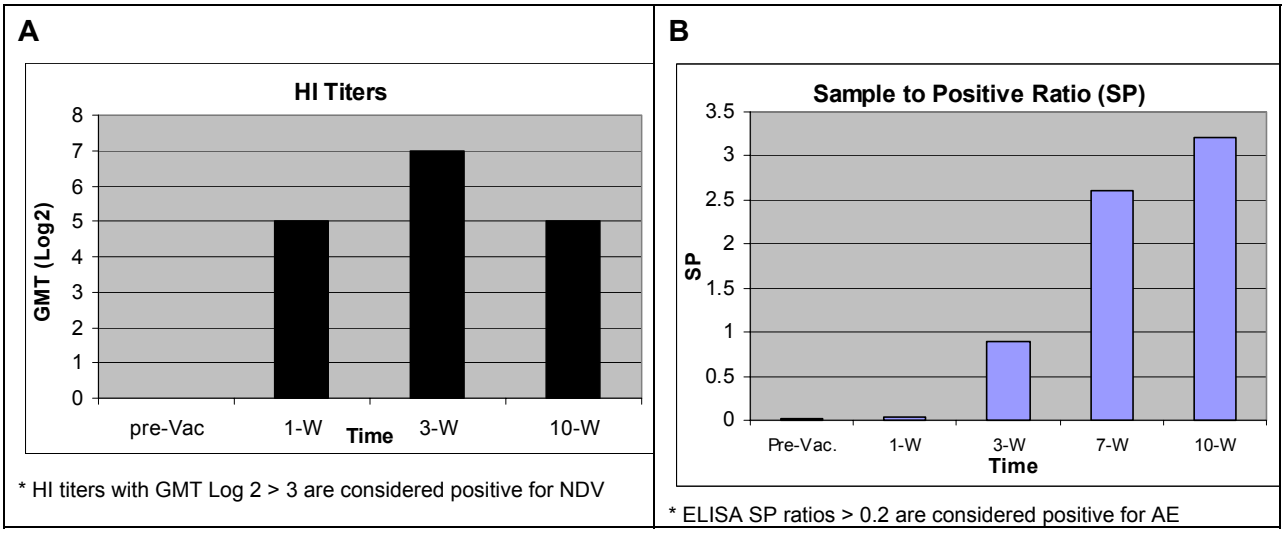

Figure 5. Blood test results for control poultry exposed to NDV (A) and avian encephlomyelitis (B) vaccine viruses in laboratory prior to field trial 1.

Figure 6. Research site showing caged pathogen-free poultry used to evaluate the potential for viral transmission from composting windrow (right).

Table 1. Cover material characteristics.

Property	Units	Cover Material *		
		Corn Stalks	Silage	Yard Waste Compost
Moisture content	%	11.07 (1.84)**	66.55 (8.07)	17.83 (2.03)
Volatile solids	%	79.36 (12.98)	79.41 (4.30)	13.15 (1.57)
Bulk density	kg/m3	37.32 (2.94)	370.66 (3.34)	669.88 (69.09)
Free air space	%	73.84 (0.98)	42.53 (3.12)	38.1 (1.26)
Permeability coefficient	m^2	585×10^{-8} (64×10^{-8})	106×10^{-8} (5×10^{-8})	7.95×10^{-8} (0.08×10^{-8})
Respiration rate	$mg_{CO2}/kg_{vs}/d$	5.96 (0.035)	3.26 (0.47)	2.64 (0.22)
C:N	-	67.96 (5.94)	21.25 (0.65)	28.84 (0.67)

* Samples collected from fresh cover material.

** Standard deviation shown in ().

Table 2. Average chemical strength of leachate from trial # 1 (warm/dry conditions).

Analysis	Corn Stalks				Silage				Yard Waste			
	Beneath carcasses	N	Beneath cover material	N	Beneath carcasses	N	Beneath cover material	N	Beneath carcasses	N	Beneath cover material	N
Total Solids (mg/l)	61037	12	2506	10	33801	5	17919	14	-	0	-	0
TOC (mg/l)	32325	12	708	10	12502	5	11696	14	-	0	-	0
Nitrate (mg/l)	310.17	12	67.50	10	199.80	5	157.93	14		0	-	0
Ammonia (mg/l)	6987	12	71	10	1088	5	960	14	-	0	-	0

Table 3. Newcastle disease survival in vials and dialysis cassettes embedded in trials 1 and 2.

Sample Time	Cover material	Trial 1 - # samples (+) / total # samples		Trial 2 - # samples (+) / total # samples	
		Vials	Cassettes	Vials	Cassettes
Day 1	Corn Stalk	0/10	*	10/10	9/9
	Silage	0/9	*	9/9	9/9
	Yard Waste	3/10	*	9/9	8/8
1-Week	Corn Stalk	0/10	0/10	6/7	--
	Silage	0/9	0/10	0/8	0/9
	Yard Waste	0/10	--	7/7	--
2-Week	Corn Stalk	0/10	0/10	0/4	--
	Silage	0/10	0/10	0/8	0/9
	Yard Waste	0/10	--	3/8	0/9
3-Week	Corn Stalk	0/10	0/10	0/8	--
	Silage	0/10	0/10	0/8	--
	Yard Waste	0/9	--	0/8	--
4-Week	Corn Stalk	0/10	0/10	0/7	--
	Silage	0/10	0/10	0/8	--
	Yard Waste	0/10	--	0/8	--
6-Week	Corn Stalk	0/10		0/8	
	Silage	0/9		0/8	
	Yard Waste	0/10		0/8	
8-Week	Corn Stalk	0/10		0/8	
	Silage	0/10		0/9	
	Yard Waste	0/10		0/8	
10-Week	Corn Stalk	0/10		0/4	
	Silage	0/10		0/8	
	Yard Waste	0/9		0/8	
Positive Control	NDV	10/10		9/9	
Negative Control	PBS	0/10		0/10	

* No dialysis cassettes were placed into windrow for testing at this time during trial 1.

-- Dialysis cassettes were damaged in composting pile, samples could not be retrieved from cassette.